

PROTOCOL

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Weymouth Initial Performance Testing

Prepared for

Algonquin Gas Transmission, LLC

PO Box 1642

Houston, TX 77251

Prepared by



Canomara LLC

PO Box 941

Simsbury, CT 06070



PROTOCOL

Weymouth Initial Performance Testing

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1 INTRODUCTION

1.1 Overview

Canomara LLC (CM) has been contracted by Algonquin Gas Transmission (AGT), a business unit of Enbridge, Inc. (Enbridge), to conduct compliance emissions testing on one newly installed Solar Taurus 60 natural gas fired turbine and one newly installed Waukesha VGF24GL emergency generator located at the Weymouth Compressor Station on Bridge Street in Weymouth, MA. The purpose of the testing is to demonstrate compliance with the initial stack testing requirements of Massachusetts Department of Environmental Protection (MassDEP) Plan Approval Application Number SE-15-027. Testing will also satisfy the requirements of 40 CFR 60 Subpart KKKK, 40 CFR 60 Subpart JJJJ and 40 CFR 63 Subpart ZZZZ. Testing of Solar turbine will be conducted within 60 days of achieving maximum capacity which is considered to occur during the 100 hour run prior to the unit going into service. Testing of the emergency generator will be conducted within 180 days of the unit going into service. All test dates will be coordinated in advance with MassDEP and testing is tentatively scheduled for October 20-22, 2020 pending acceptance of this test protocol and test dates.

1.2 Contact Information

Evan Bali of CM will be the project manager for the test program. Frank Pike of AGT/Enbridge will coordinate sampling with plant operations at the compressor station. Contact information is summarized below.

Frank Pike
Enbridge, Inc.
890 Winter St. Suite 300
Waltham, MA 02451
617.560.1322
frank.pike@enbridge.com

Evan Bali, QSTI
Canomara LLC
PO Box 941
Simsbury, CT 06070
860.865.1166 x802
evan@canomara.com

2 SCOPE OF WORK

2.1 Test Matrix

CM will conduct emissions testing at the exhaust ductwork of the Solar Taurus 60 in accordance with US EPA test methods while the turbine is operating at plus or minus 25 percent of 100 percent peak load. Table 2-1 contains the turbine test matrix. CM will also conduct emissions testing at the exhaust stack of the Waukesha VGF24GL in accordance with US EPA test methods while the generator is operating within 10 percent of 100 percent peak load. Table 2-2 contains the generator test matrix.

**Table 2-1: Solar Turbine Test Matrix
Weymouth Compressor Station**

Parameter	Methods	Tests and Duration	Measurements
Oxygen (O ₂) Carbon Dioxide (CO ₂)	EPA 3a	3, 60-minute	%
Oxides of Nitrogen (NO _x)	EPA 7e	3, 60-minute	ppmvd @ 15% O ₂ lb/MMBtu lb/hr, tpm, tpy
Carbon Monoxide (CO)	EPA 10	3, 60-minute	ppmvd @ 15% O ₂ lb/MMBtu lb/hr, tpm, tpy
Volatile Organic Compounds (VOC)	EPA 25a/18	3, 60-minute	ppmvd @ 15% O ₂ lb/MMBtu lb/hr, tpm, tpy
Particulate Matter (PM/PM10/PM2.5) ¹	EPA 5/202	3, 240-minute	lb/MMBtu tpm tpy
Formaldehyde	EPA 323 (mod)	3, 60-minute	tpm tpy
Benzene	TO-15	3, 60-minute	tpm tpy

1. PM10/PM2.5 will be conducted in accordance with EPA Method 5 and 202 where total particulate matter will be reported as PM10 by combining filterable and condensable particulate matter.

**Table 2-2: Emergency Generator Test Matrix
Weymouth Compressor Station**

Parameter	Methods	Tests and Duration	Emission Units ¹
O ₂ /CO ₂	EPA 3A	3, 60-minute	%
NO _x	EPA 7e	3, 60-minute	ppmvd @ 15% O ₂ g/HP-hr lb/hr
CO	EPA 10	3, 60-minute	
VOC	EPA 18/25a	3, 60-minute	

1. Emission rates will be determined using EPA Methods 1-4 or EPA Method 19 depending on availability of real time fuel flow data during the testing.

2.2 Test Schedule

Table 2-3 contains the schedule for the emissions testing.

Table 2-3: Test Schedule

Day	Activities	Crew Size	Time
1	Equipment Setup	3	8 hrs
2	Turbine- Two 240-minute tests	3	10 hrs
3	Turbine- One 240-minute test	3	8 hrs
4	Generator- Three 60-minute tests	3	8 hrs
5	Contingency	3	8 hrs

3 PROCESS DESCRIPTION

The Weymouth Compressor Station is located on Bridge Street in Weymouth, MA and is one of several compressor stations operated along Algonquin Gas Transmission LLC's interstate natural gas pipeline system.

The Solar Taurus 60 compressor turbine is fired exclusively on pipeline quality natural gas and has a minimum Solar guarantee ISO rating of 7,451 hp and 67.14 MMBtu/hr. Solar's proprietary "So-Lo-NOx" staged combustion system is utilized for the control of NO_x emissions and the turbine is equipped with an oxidation catalyst.

Operating parameters will be recorded by the facility at minimum of 15-minute intervals during the turbine emissions testing. The following parameters will be recorded.

-) Fuel flow rate
-) Fuel compositional analysis
-) Compressor suction and discharge pressures
-) Compressor suction and discharge temperatures
-) Brake horsepower
-) Turbine and gas producer speeds
-) Other available and pertinent data

The Waukesha VGF24GL emergency spark ignition engine generator set is fired exclusively on pipeline quality natural gas and is rated at 585 brake horsepower.

Operating parameters will be recorded by the facility at minimum of 15-minute intervals during the generator emissions testing. The following parameters will be recorded.

-) Fuel flow rate
-) Fuel compositional analysis
-) KW output
-) Engine Speed
-) Other available and pertinent data

4 SAMPLING & ANALYTICAL PROCEDURES

Table 4-1 and 4-2 list the reference methods which will be followed to conduct emissions testing. Appendix A contains detailed descriptions of the methods to be used during this test program.

Table 4-1: Turbine Reference Methods

Method	Description
EPA 1	Sample and Velocity Traverses for Stationary Sources
EPA 2	Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)
EPA 3a	Determination of Oxygen and Carbon Dioxide Concentrations In Emissions from Stationary Sources (Instrumental Analyzer Procedure)
EPA 4	Determination of Moisture Content in Stack Gases
EPA 5	Determination of Particulate Matter from Stationary Sources
EPA 7e	Determination of Nitrogen Oxide Emissions from Stationary Sources (Instrumental Analyzer Procedure)
EPA 10	Determination of Carbon Monoxide Emissions from Stationary Sources (Instrumental Analyzer Procedure)
EPA 18	Gaseous Organic Compound Emissions by Gas Chromatography (Direct Interface Method)
EPA 25a	Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer
EPA 202	Method for Determining Condensable Particulate Emissions from Stationary Sources
EPA 323	Measurement of Formaldehyde Emissions from Natural Gas Fired Stationary Sources (modified)
TO-15	Determination of Volatile Organic Compounds in Air Collected in Specially Prepared Canisters and Analyzed by GC/MS

Table 4-2: Generator Reference Methods

Method ¹	Description
EPA 1	Sample and Velocity Traverses for Stationary Sources
EPA 2	Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)
EPA 3a	Determination of Oxygen and Carbon Dioxide Concentrations In Emissions from Stationary Sources (Instrumental Analyzer Procedure)
EPA 4	Determination of Moisture Content in Stack Gases
EPA 7e	Determination of Nitrogen Oxide Emissions from Stationary Sources (Instrumental Analyzer Procedure)
EPA 10	Determination of Carbon Monoxide Emissions from Stationary Sources (Instrumental Analyzer Procedure)
EPA 18	Gaseous Organic Compound Emissions by Gas Chromatography (Integrated Bag Sampling and Analysis)
EPA 25a	Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer

1. Emission rates will be determined using EPA Methods 1-4 or EPA Method 19 depending on availability of real time fuel flow data during the testing.

Table 4-3 and 4-4 contain information about the instrumental reference method analyzers and measurement ranges to be used during this test program.

Table 4-3: Turbine Instrumental Reference Method Analyzers

Constituent	Analyzer	Detector	Span
O ₂	TAPI T200H	Paramagnetic	22 %
CO ₂	TAPI T300M	Non-Dispersive Infrared	18 %
NO _x	TAPI 200H	Chemiluminescent	25 ppm ¹
CO	TAPI T300M	Non-Dispersive Infrared	10 ppm
VOC	Vig 20 SRI 8610	Flame Ionization Gas Chromatography	10 ppm

1. A 10 ppm range may be used depending on the observed stack concentration.

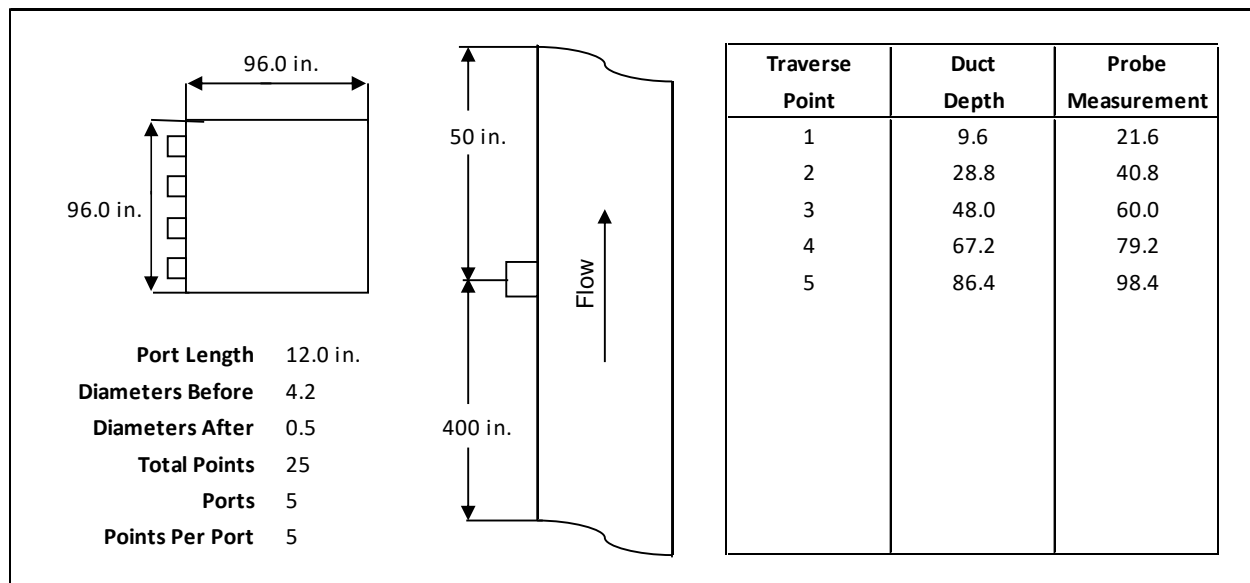
Table 4-4: Generator Instrumental Reference Method Analyzers

Constituent	Analyzer	Detector	Span
O ₂	TAPI T200H	Paramagnetic	22 %
CO ₂	TAPI T300M	Non-Dispersive Infrared	18 %
NO _x	TAPI 200H	Chemiluminescent	500 ppm
CO	TAPI T300M	Non-Dispersive Infrared	500 ppm
VOC	Vig 20 SRI 8610	Flame Ionization Gas Chromatography	4,500 ppm

4.1 Sampling Locations

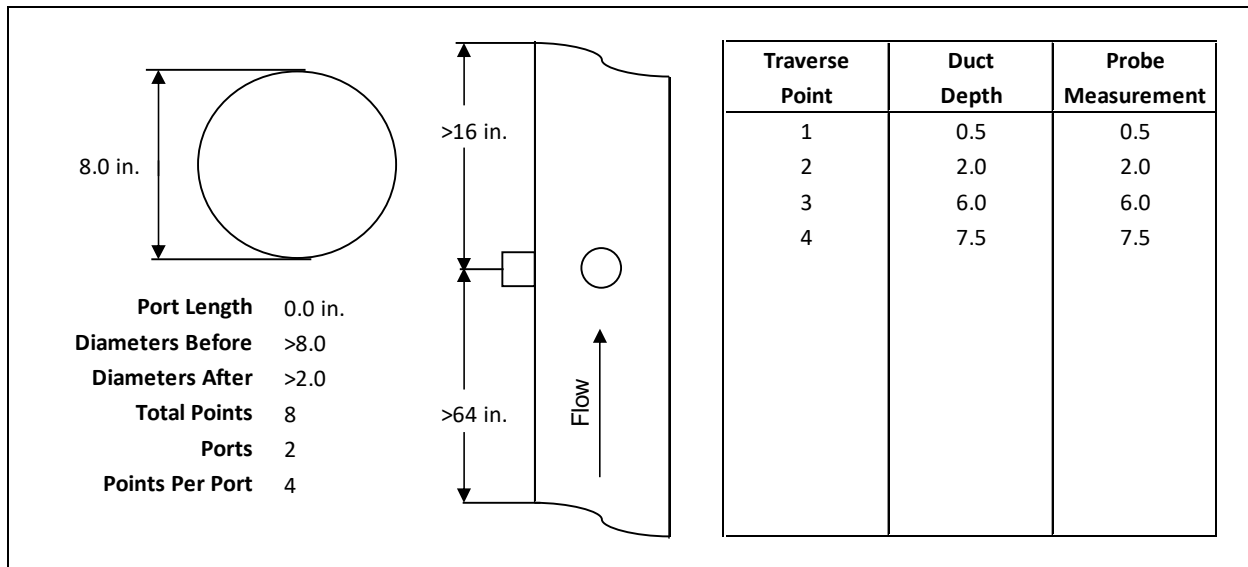
Turbine sampling will be conducted using five ports on the 96 x 96-inch horizontal exhaust duct prior to the vertical stack. A three-point stratification test will be conducted in accordance with EPA Method 7e and particulate traverse points for the turbine are presented in Figure 4-1.

Figure 4-1: Turbine Traverse Points



The generator is equipped with two sampling ports in the 8-inch diameter stack. The generator ports are located more than 8 diameters downstream of a flow disturbance and more than 2 diameters upstream of the stack exit. A three-point stratification test will be conducted in accordance with EPA Method 7e and EPA Method 1 traverse points are shown in Figure 4-2.

Figure 4-2: Generator Traverse Points



5 QUALITY ASSURANCE

CM's quality assurance program is designed so that work is performed by competent, experienced individuals using properly calibrated equipment, approved procedures for sample collection, recovery, and analysis and proper documentation. This ensures the integrity of data collected, processed, and reported on each project.

All final project deliverables are reviewed by an independent peer reviewer. Additional project specific quality assurance requirements are based on client contracts, local, state, or regional environmental regulations, and quality requirements and guidelines included in published sampling and analytical methods. Specific quality assurance procedures and acceptance criteria for this test program can be found in Appendix A.

APPENDIX A

SAMPLING METHODS

EPA Method 1

Sample and Velocity Traverses for Stationary Sources

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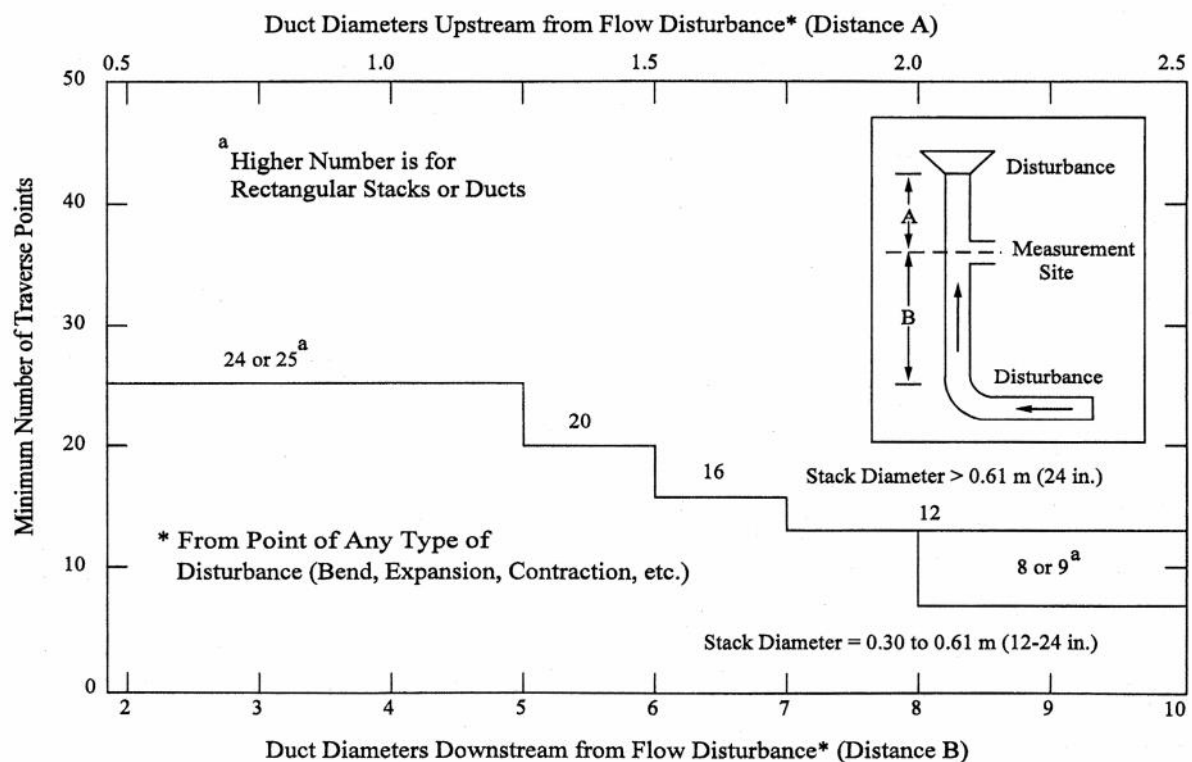
SUMMARY

A measurement site where the effluent stream is flowing in a known direction is selected, and the cross-section of the stack is divided into a number of equal areas. Traverse points are then located within each of these equal areas.

SITE SELECTION

- Sampling or velocity measurements must be taken at a position at least 2 stack diameters downstream and a half diameter upstream from any flow disturbance.
- The minimum allowed number of traverse points can be used when there is at least 8 stack diameters downstream and 2 stack diameters upstream.
- For particulate traverses refer to table 1 to determine the required number of traverse points
- For velocity traverses refer to table 2 to determine the required number of traverse points
- For circular stacks, locate the traverse points on two perpendicular diameters according to the diameter percentages listed in table 3.
- For rectangular stacks, divide the stack into as many equal areas as traverse points and locate each traverse point in the center of each area.
- Verify the absence of cyclonic flow using a Type S pitot tube and the manometer nulling technique.

Table 1
Particulate Traverses



Revised: 08/2/2018

EPA Method 1

Sample and Velocity Traverses for Stationary Sources

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Table 2
Velocity Traverses

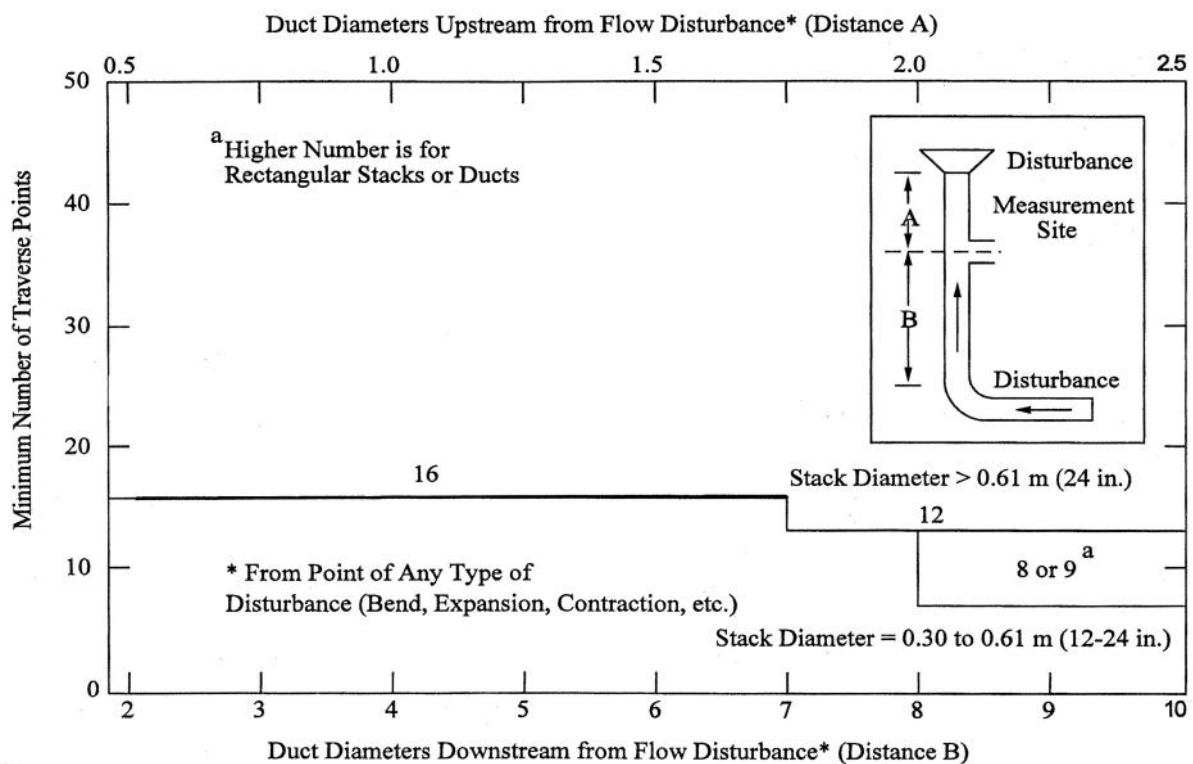


Table 3
Location of Traverse Points in Circular Stacks

Traverse Point	Number of Traverse Points on a Diameter				
	4	6	8	10	12
1	6.7	4.4	3.2	2.6	2.1
2	25.0	14.6	10.5	8.2	6.7
3	75.0	29.6	19.4	14.6	11.8
4	93.3	70.4	32.3	22.6	17.7
5		85.4	67.7	34.2	25.0
6		95.6	80.6	65.8	35.6
7			89.5	77.4	64.4
8			96.8	85.4	75.0
9				91.8	82.3
10				97.4	88.2
11					93.3
12					97.9

Revised: 08/2/2018

EPA Method 2

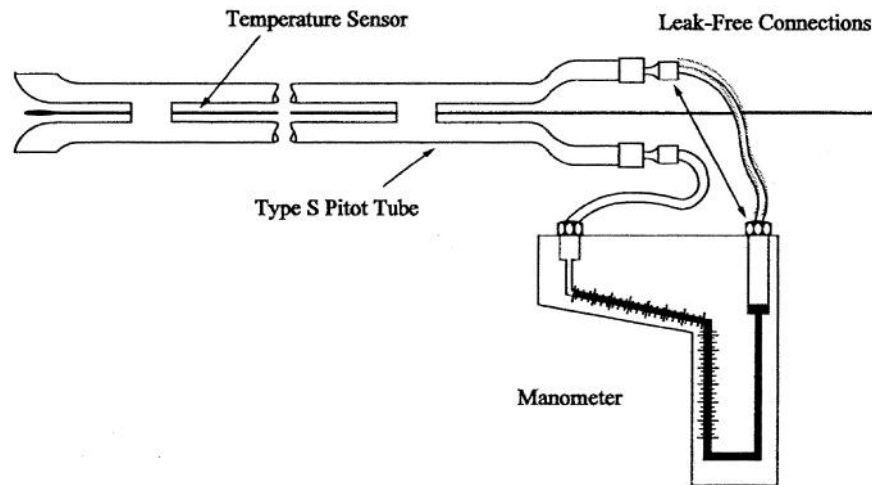
Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)

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SUMMARY

The average gas velocity in a stack is determined from the gas density and from measurement of the average velocity head with a Type S (Staustscheibe or reverse type) pitot tube.

MEASUREMENT EQUIPMENT



- Type S pitot tube constructed of stainless steel or other appropriate metal with a known coefficient.
- Leak free flexible tubing
- Differential pressure gauge such as in inclined manometer with a 10-inch water column with gradations of 0.01 - 0.1 inH₂O for p readings greater than 0.05 inH₂O.
- Temperature sensor such as a K-Type thermocouple attached to the pitot tube.

SAMPLING PROCEDURE

- It is recommended that a pre-test leak check be conducted by blowing into the positive side of the pitot tube until at least 3.0 inH₂O is registered on the manometer. Block off the opening and observe that the reading remains stable for at least 15 seconds. Follow the same procedure on the negative side of the pitot tube using suction.
- Measure velocity head and temperature and the traverse points determined by EPA Method 1.
- Measure the static pressure in the stack.
- Determine the atmospheric pressure.
- Determine the stack gas dry molecular weight using EPA Method 3 or 3a.
- Determine moisture content using EPA Method 4, wet-bulb/dry-bulb, or saturation.

QUALITY ASSURANCE

- Pitot tube calibration by either geometric or wind tunnel measurements.
- Thermocouple calibration using an ice bath and boiling water.
- Pitot tube leak checks conducted before and after each velocity traverse.
- Maintain a properly leveled and zeroed manometer.

Revised: 08/2/2018

EPA Method 3a

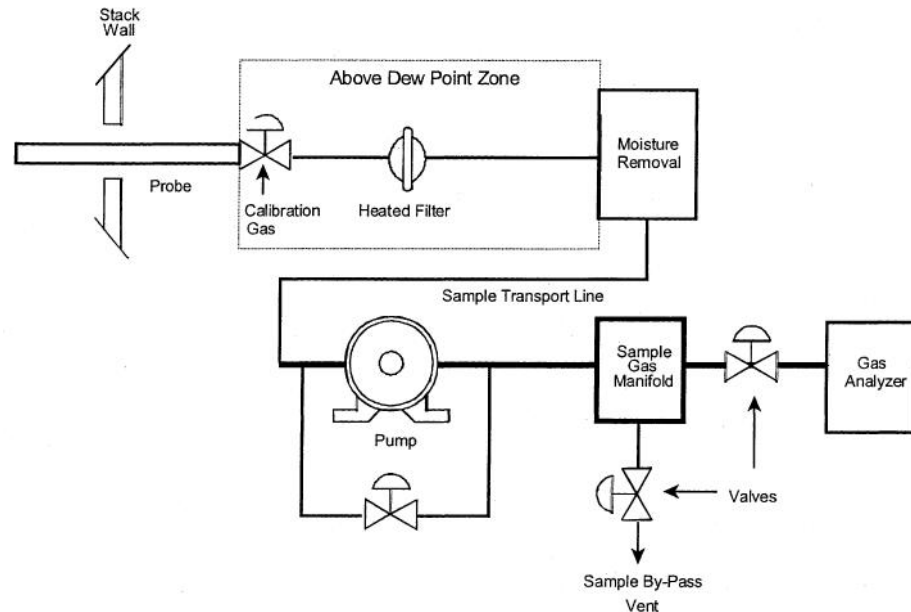
Determination of Oxygen and Carbon Dioxide Concentrations In Emissions from Stationary Sources (Instrumental Analyzer Procedure)

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SUMMARY

Effluent gas is continuously conveyed to an analyzer for measuring the concentration of O₂ or CO₂.

SAMPLING TRAIN



Components:

- Glass or stainless steel probe of sufficient length to traverse required sample points.
- An in-stack or out-of-stack filter made of material which is non-reactive to the sample gas. The filter is not required where no significant particulate matter is present.
- Sample line made of Teflon or other material that does not absorb or alter the sample gas.
- Condenser or dryer to remove moisture from the sample gas if measuring on a dry basis.
- Leak-free pump constructed of non-reactive material to pull sample through the system at a sufficient rate to minimize the response time.
- Manifold constructed of non-reactive material to allow the introduction of calibration gases either directly to the analyzer or into the measurement system at the probe and to direct a portion of the sample to the analyzer while diverting the rest of the sample to a by-pass discharge vent.
- Analyzer capable of meeting all performance requirements that continuously measures O₂ or CO₂.
- Computer based data acquisition system for recording measurements.

Revised: 08/2/2018

EPA Method 3a

Determination of Oxygen and Carbon Dioxide Concentrations In Emissions from Stationary Sources (Instrumental Analyzer Procedure)

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SAMPLING PROCEDURES

- Assemble the sampling system and conduct a leak check.
- Confirm that all calibration gas certifications are complete and not expired.
- Conduct an analyzer calibration error test.
- Conduct an initial system bias check and response time test.
- Perform a stratification test to determine the number of sample traverse points unless the measurement is only being used to determine the stack gas molecular weight in which case a single measurement point may be used.
- Position the probe at the first sampling point and purge the system for at least two times the response time. Traverse all required points sampling for equal time at each.
- Conduct a post-run system bias and drift assessment check.

QUALITY ASSURANCE

Measurement System:

- Calibration error is verified to be within $\pm 2\%$ of the calibration span or $\pm 0.5\%$ difference
- System bias is verified to be within $\pm 5\%$ of the calibration span or $\pm 0.5\%$ difference
- Drift is verified to be within $\pm 3\%$ of the calibration span or $\pm 0.5\%$ difference

O₂ or CO₂ Analyzer:

- Analyzer used for testing has undergone manufacturer interference checks
- Analyzer resolution is $< 2.0\%$ full-scale range

Calibration Gas:

- Calibration uncertainty of $\pm 2\%$ certified value
- Low-level gas $< 20\%$ of calibration span
- Mid-level gas 40-60% of calibration span
- High-level gas sets the calibration span with test measurements 20-100% of this value

Data:

- Data collection and calculations are conducted on a reviewed computer based system
- Data resolution $\pm 0.5\%$ full-scale range
- Data recording frequency of 1-minute average
- Minute averages \pm calibration span
- Run average \pm calibration span

Revised: 08/2/2018

EPA Method 3a

Determination of Oxygen and Carbon Dioxide Concentrations In Emissions from Stationary Sources (Instrumental Analyzer Procedure)

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CALCULATIONS

Analyzer Calibration Error:

$$ACE = \frac{C_{DIR} - C_V}{C} \times 100$$

ACE Analyzer calibration error, percent of calibration span

C_V Manufacturer certified concentration of a calibration gas (low, mid, high), ppmv

C_{DIR} Measured concentration of a calibration gas when introduced in direct calibration mode, ppmv

CS Calibration span, ppmv

System Bias:

$$SB = \frac{C_S - C_{DIR}}{C} \times 100$$

SB System bias, percent of calibration span

C_S Measured concentration of a calibration gas when introduced in system calibration mode, ppmv

CS Calibration span, ppmv

Drift Assessment:

$$D = SB_{final} - SB_i$$

D Drift assessment, percent of calibration span

SB_{final} Post-run system bias, percent of calibration span

SB_i Pre-run system bias, percent of calibration span

Effluent Gas Concentration:

$$C_{Gas} = (C_{Avg} - C_O) \times \frac{C_{MA}}{C_M - C_O}$$

C_{Gas} Average effluent gas concentration adjusted for bias, ppmv

C_{Avg} Average unadjusted gas concentration indicated by data recorder for the test run, ppmv

C_O Average of initial and final system bias responses from the low-level (or zero) calibration gas, ppmv

C_{MA} Actual concentration of the upscale calibration gas, ppmv

C_M Average of initial and final system bias responses for the upscale calibration gas, ppmv.

Revised: 08/2/2018



EPA Method 4

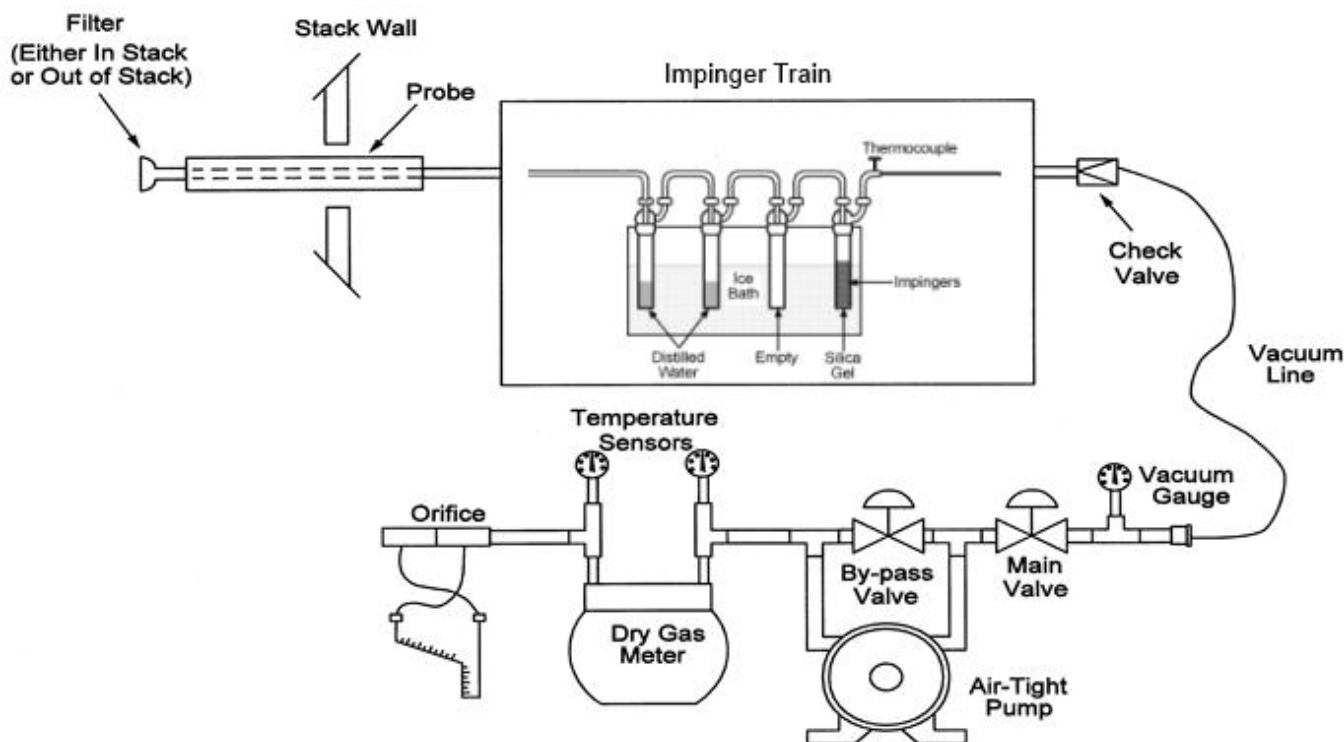
Determination of Moisture Content in Stack Gases

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SUMMARY

A gas sample is extracted from the source at a constant rate. Moisture is removed from the sample stream by condensation and moisture is determined either gravimetrically or volumetrically.

SAMPLING TRAIN



Components:

- Stainless steel or glass probe sufficiently heated to prevent condensation.
- In-stack or heated out-of-stack filter
- Teflon sample line
- 4 impingers connected in series placed in an ice bath (impinger exit < 68 °F)
 1. Modified Greenburg-Smith, ~100 ml water
 2. Greenburg-Smith, ~100 ml water
 3. Modified Greenburg-Smith, empty
 4. Modified Greenburg-Smith, indicating silica gel
- Umbilical with leak-free vacuum line
- Vacuum gauge, leak-free pump, temperature sensors and a calibrated dry gas meter
- Inclined manometer or equivalent for measuring orifice values

Revised: 08/2/2018

EPA Method 4

Determination of Moisture Content in Stack Gases

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SAMPLING PROCEDURES

- Weigh the impinger train.
- Conduct a leak check from the tip of the probe at a vacuum of 15 inHg. Ensure that the leak rate is 0.020 cfm before starting a test run.
- Place the probe at the first sampling point.
- Begin sampling at a rate of approximately 0.75 cubic feet per minute. Collect sample data every 10 minutes including delta H, impinger outlet temperature, and dry gas meter inlet and outlet temperature.
- Conduct a post-test leak check from the tip of the probe or first impinger at a vacuum higher than the highest vacuum observed during sampling.

RECOVERY PROCEDURES

- Weigh the impinger train.
- Record the difference between the Post and Pre impinger train weights.
- Calculate the moisture content.

QUALITY ASSURANCE

Equipment:

- Dry gas meters are calibrated annually and after each field program.
- All glassware is cleaned prior to field use.
- Impinger exit temperature is monitored during testing to verify compliance with method specification.
- A leak check is conducted post run at a vacuum equal to or greater than the maximum value reached during the test run.
- The dry gas meter calibration factor is verified after field use to be within 5% of the annual value.
- Temperature meters are calibrated annually and after each field use.

Data:

- Field data are recorded on prepared forms.
- Only reviewed spreadsheets are used to conduct data reduction calculations.
- All data and deliverables undergo peer review with a signoff form.

Revised: 08/2/2018



EPA Method 4

Determination of Moisture Content in Stack Gases

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CALCULATIONS

Dry Gas Volume:

$$V_{m(s)} = V_m Y \frac{T_s \left(P_b + \frac{\Delta}{13.6} \right)}{T_m P_s}$$

$V_{m(std)}$ Volume of gas sample measured by the dry gas meter, corrected to standard conditions, dscf

V_m Volume of gas sample as measured by dry gas meter, dcf

Y Dry gas meter calibration factor

T_{std} Standard absolute temperature, 528 °R

P_{bar} Barometric pressure at the sampling site, inHg

H Average pressure differential across the orifice meter, inH₂O

T_m Absolute average DGM temperature, °R

P_{std} Standard absolute pressure, 29.92 inHg

Volume of Water Vapor Condensed:

$$V_{w(s)} = K_2 V_{lc}$$

$V_{w(std)}$ Volume of water vapor in the gas sample, corrected to standard conditions, scf

K_2 0.04706 ft/ml for English units

V_{lc} Total volume of liquid collected in impingers and silica gel

Moisture Content:

$$B_w = \frac{V_{w(s)}}{V_{m(s)} + V_{w(s)}}$$

B_{ws} Water vapor in the gas stream, proportion by volume

$V_{w(std)}$ Volume of water vapor in the gas sample, corrected to standard conditions, scf

EPA Method 5

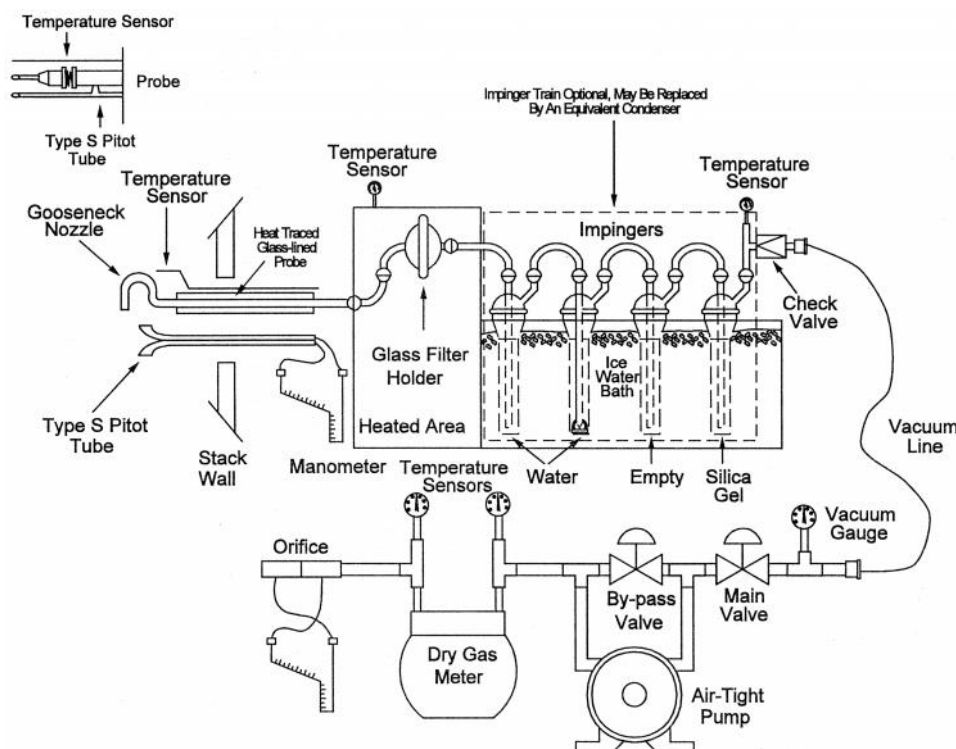
Determination of Particulate Matter from Stationary Sources

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SUMMARY

Particulate matter (PM) is withdrawn isokinetically from the source and collected on a glass fiber filter maintained at a temperature of 248 ± 25 °F. The PM mass, including any material that condenses at or above the filtration temperature, is determined gravimetrically after the removal of uncombined water.

SAMPLING TRAIN



Components:

-) Stainless steel or glass button-hook nozzle with a sharp, tapered leading edge appropriately sized for isokinetic sampling
-) Heated quartz or borosilicate glass lined probe (248 ± 25 °F) with attached Type S pitot tube and Type K thermocouple
-) Heated 3-inch glass fiber filter in glass holder with Teflon frit (248 ± 25 °F)
-) 4 impingers connect in series placed in an ice bath (impinger exit 68 °F)
 1. Modified Greenburg-Smith, ~100 ml water
 2. Greenburg-Smith, ~100 ml water
 3. Modified Greenburg-Smith, empty
 4. Modified Greenburg-Smith, indicating silica gel
-) Umbilical with leak-free vacuum line
-) Vacuum gauge, leak-free pump, temperature sensors and a calibrated dry gas meter
-) Dual inclined manometer or equivalent for measuring velocity head and orifice values

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EPA Method 5

Determination of Particulate Matter from Stationary Sources

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SAMPLING PROCEDURES

-) Select sampling site and minimum number of sampling points according to EPA Method 1. Mark an appropriately sized sampling probe with the points calculated for the location. Determine the sampling time per point 2 minutes.
-) Determine appropriate nozzle size necessary to maintain isokinetic sampling conditions based on stack pressure, temperature, and velocity head range according EPA Method 2, stack molecular weight according to EPA Method 3/3a, and stack moisture content according to EPA Method 4.
-) Calculate a k-factor based off the selected nozzle size and stack conditions. Assemble the sampling train as described above, weigh the impingers and place crushed ice around them.
-) Conduct a leak check from the tip of the nozzle at a vacuum of 15 inHg. Ensure that the leak rate is 0.020 cfm before starting a test run.
-) Place the probe at the first sampling point once all temperatures are within the required range.
-) Begin sampling, making adjustments as necessary to maintain isokinetic sampling rate within $\pm 10\%$.
-) Traverse the stack using the predetermined sampling points.
-) Conduct a post-test leak check at a vacuum higher than the highest vacuum observed during sampling.
-) Calculate % isokinetic for the run to validate the test.

RECOVERY PROCEDURES

-) Weigh the impingers to determine moisture gain.
-) Container 1 - Carefully remove the filter from its holder and place it in a labeled glass or polyethylene petri dish.
-) Container 2 – Rinse and brush the nozzle, probe liner, and front half of the filter holder with reagent grade acetone (0.001 % residue) into a labeled glass or polyethylene sample container with a Teflon or other chemically resistant screw cap liner.
-) Blank – Collect 200 ml of acetone from the wash bottle used to conduct recoveries into a labeled sample jar.

EPA Method 5

Determination of Particulate Matter from Stationary Sources

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QUALITY ASSURANCE

Equipment:

-) Pitot tubes, thermocouples, nozzles, and dry gas meters are calibrated annually.
-) All glassware is cleaned prior to field use.
-) Probe, filter, and impinger exit temperatures are carefully monitored during testing to ensure the values are maintained within the appropriate range.
-) The entire sampling train is leak checked post run from the tip of the nozzle at a vacuum equal to or greater than the maximum value reached during the test run.
-) Sampling rate is verified to be within 10% isokinetic variation (90%-110%).
-) The dry gas meter calibration factor is verified after field use to be within 5% of the annual value.

Samples:

-) New containers are used to collect samples.
-) Each sample container is clearly labeled.
-) A chain of custody is generated for all samples.
-) Samples are transported upright in protective packaging.

Data:

-) Field data are recorded on prepared forms.
-) Only reviewed spreadsheets are used to conduct data reduction calculations.
-) All data and deliverables undergo peer review with a signoff form.

EPA Method 5

Determination of Particulate Matter from Stationary Sources

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CALCULATIONS

Dry Gas Volume:

$$V_{m(s)} = V_m Y \frac{T_s \left(P_b + \frac{\Delta}{13.6} \right)}{T_m P_s}$$

$V_{m(std)}$ Volume of gas sample measured by the dry gas meter, corrected to standard conditions, dscf

V_m Volume of gas sample as measured by dry gas meter, dcf

Y Dry gas meter calibration factor

T_{std} Standard absolute temperature, 528 °R

P_{bar} Barometric pressure at the sampling site, inHg

H Average pressure differential across the orifice meter, inH₂O

T_m Absolute average DGM temperature, °R

P_{std} Standard absolute pressure, 29.92 inHg

Volume of Water Vapor Condensed:

$$V_{w(s)} = K_2 V_{lc}$$

$V_{w(std)}$ Volume of water vapor in the gas sample, corrected to standard conditions, scf

K_2 0.04706 ft/ml for English units

V_{lc} Total volume of liquid collected in impingers and silica gel

Moisture Content:

$$B_w = \frac{V_{w(s)}}{V_{m(s)} + V_{w(s)}}$$

B_{ws} Water vapor in the gas stream, proportion by volume

$V_{w(std)}$ Volume of water vapor in the gas sample, corrected to standard conditions, scf

Particulate Concentration:

$$C_s = \frac{K_3 m_n}{V_{m(s)}}$$

C_s Concentration of particulate matter in stack gas, dry basis, corrected to standard conditions, gr/dscf

K_3 0.0154 gr/mg for English units

M_n Total amount of particulate matter collected, mg

Revised: 06/4/2020



EPA Method 5

Determination of Particulate Matter from Stationary Sources

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CALCULATIONS (CONTINUED)

Isokinetic Variation:

$$I = \frac{100T_s \left[K_4 V_{lc} + \frac{(V_m Y)}{T_m} \left(P_{bar} + \frac{\Delta H}{13.6} \right) \right]}{60 \theta v_s P_s A_n}$$

T_s	Absolute average stack gas temperature, °R
K_4	0.002669 ((inHg)(ft))/((ml)(°R)) for English units
V_{lc}	Total volume of liquid collected in impingers & silica gel, ml
	Total sampling time, min
V_s	Stack gas velocity, ft/sec
P_s	Absolute stack gas pressure, inHg
A_n	Cross-sectional area of nozzle, ft ²

Alternative Post-Test Dry Gas Meter Calibration (EPA Method 5, Section 16.3)

$$Y_{qa} = \frac{q}{V_m} \left(\frac{0.0319 (T_m + 460) \times 29}{DH_{@} [P_b + (DH_{avg}/13.6)] M_d} \right)^{0.5} (DH^{0.5})_{avg}$$

Y_{qa} = Dry gas meter calibration check value, dimensionless

q = Total run time, min

V_m = Total sample volume measured by dry gas meter, dcf

T_m = Average dry gas meter temperature, °F

P_b = Barometric pressure, in. Hg

0.0319 = (29.92/528)(0.75)² (in. Hg/°R) cfm²

DH_{avg} = Average orifice meter differential, in H₂O

$DH_{@}$ = Orifice meter calibration coefficient, in H₂O

M_d = Dry molecular weight of stack gas, lb/lb-mole

29 = Dry molecular weight of air, lb/lb-mole

13.6 = Specific gravity of mercury

$$\text{Difference} = \frac{(Y_{qa} - Y)}{Y} \text{ within } \pm 5\%$$

Revised: 06/4/2020



EPA Method 7e (with EPA Method 19 Emission Rate Calculation Using Oxygen-Based Fuel Factor)

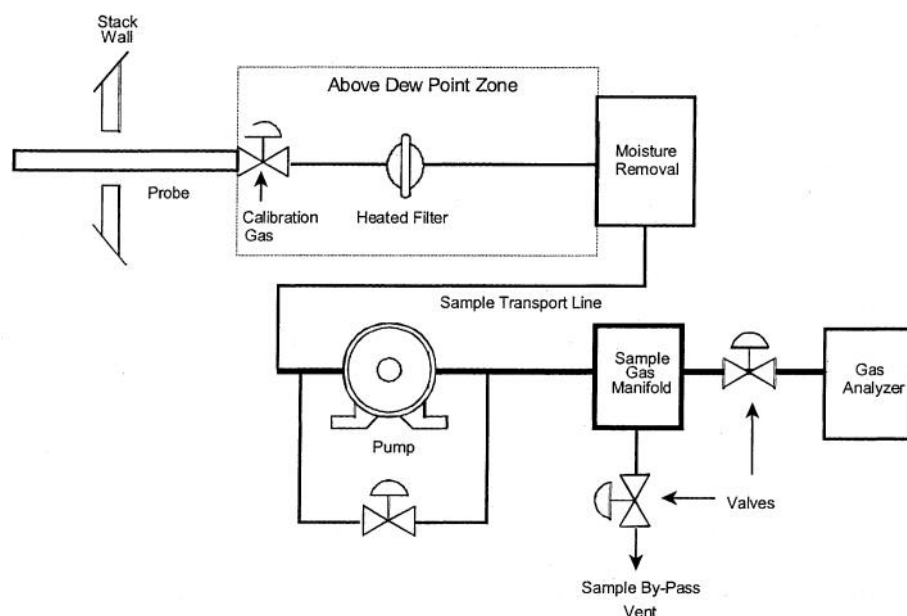
Determination of Nitrogen Oxides Emissions from Stationary Sources
(Instrumental Analyzer Procedure)

Page 1 / 4

SUMMARY

A sample of the effluent gas is continuously conveyed to the analyzer for measuring the concentration of NO_x as NO_2 . NO and NO_2 may be measured separately or simultaneously, but for the purposes of this method NO_x is the sum of NO and NO_2 .

SAMPLING TRAIN



Components:

-) Glass or stainless steel probe of sufficient length to traverse required sample points.
-) An in-stack or out-of-stack filter made of material which is non-reactive to the sample gas. The filter is not required where no significant particulate matter is present.
-) Heated sample line (250°F) made of Teflon or other material that does not absorb or alter the sample gas.
-) Condenser or dryer to remove moisture from the sample gas if measuring on a dry basis.
-) Leak-free pump constructed of non-reactive material to pull sample through the system at a sufficient rate to minimize the response time.
-) Manifold constructed of non-reactive material to allow the introduction of calibration gases either directly to the analyzer or into the measurement system at the probe and to direct a portion of the sample to the analyzer while diverting the rest of the sample to a by-pass discharge vent.
-) An analyzer capable of meeting all performance requirements that continuously measures NO_x .
-) Computer based data acquisition system for recording measurements.

Revised: 08/4/2020

EPA Method 7e (with EPA Method 19 Emission Rate Calculation Using Oxygen-Based Fuel Factor)

Determination of Nitrogen Oxides Emissions from Stationary Sources
(Instrumental Analyzer Procedure)

Page 2 / 4

SAMPLING PROCEDURES

-) Assemble the sampling system and conduct a leak check.
-) Confirm that all calibration gas certifications are complete and not expired.
-) Conduct an analyzer calibration error test.
-) Conduct an initial system bias check and response time test.
-) Conduct an NO₂ to NO conversion efficiency test if the analyzer being used performs this conversion to measure NO_x.
-) Perform a stratification test to determine the number of sample traverse points.
-) Position the probe at the first sampling point and purge the system for at least two times the response time. Traverse all required points sampling for equal time at each.
-) Conduct a post-run system bias and drift assessment check.

QUALITY ASSURANCE

Measurement System:

-) Calibration error is verified to be within $\pm 2\%$ of the calibration span or ± 0.5 ppmv difference
-) System bias is verified to be within $\pm 5\%$ of the calibration span or ± 0.5 ppmv difference
-) Drift is verified to be within $\pm 3\%$ of the calibration span or ± 0.5 ppmv difference

NO_x Analyzer:

-) Analyzer used for testing has undergone manufacturer interference checks
-) Analyzer resolution is $< 2.0\%$ full-scale range
-) Converter efficiency is verified to be 90% or demonstrate a decrease from NO_{xPeak} of 2%

Calibration Gas:

-) Calibration uncertainty of 2% certified value
-) Low-level gas $< 20\%$ of calibration span
-) Mid-level gas 40-60% of calibration span
-) High-level gas sets the calibration span with test measurements 20-100% of this value
-) Converter efficiency gas concentration is 40-60 ppm NO₂

Data:

-) Data collection and calculations are conducted on a reviewed computer based system
-) Data resolution 0.5% full-scale range
-) Data recording frequency of 1-minute average
-) Minute averages calibration span
-) Run average calibration span

Revised: 08/4/2020



EPA Method 7e (with EPA Method 19 Emission Rate Calculation Using Oxygen-Based Fuel Factor)

Determination of Nitrogen Oxides Emissions from Stationary Sources
(Instrumental Analyzer Procedure)

Page 3 / 4

CALCULATIONS

Analyzer Calibration Error:

$$ACE = \frac{C_{DIR} - C_V}{C} \times 100$$

ACE Analyzer calibration error, percent of calibration span

C_V Manufacturer certified concentration of a calibration gas (low, mid, high), ppmv

C_{DIR} Measured concentration of a calibration gas when introduced in direct calibration mode, ppmv

CS Calibration span, ppmv

System Bias:

$$SB = \frac{C_S - C_{DIR}}{C} \times 100$$

SB System bias, percent of calibration span

C_S Measured concentration of a calibration gas when introduced in system calibration mode, ppmv

CS Calibration span, ppmv

Drift Assessment:

$$D = SB_{final} - SB_i$$

D Drift assessment, percent of calibration span

SB_{final} Post-run system bias, percent of calibration span

SB_i Pre-run system bias, percent of calibration span

Effluent Gas Concentration:

$$C_{Gas} = (C_{Avg} - C_O) \times \frac{C_{MA}}{C_M - C_O}$$

C_{Gas} Average effluent gas concentration adjusted for bias, ppmv

C_{Avg} Average unadjusted gas concentration indicated by data recorder for the test run, ppmv

C_O Average of initial and final system bias responses from the low-level (or zero) calibration gas, ppmv

C_{MA} Actual concentration of the upscale calibration gas, ppmv

C_M Average of initial and final system bias responses for the upscale calibration gas, ppmv.

Revised: 08/4/2020



EPA Method 7e (with EPA Method 19 Emission Rate Calculation Using Oxygen-Based Fuel Factor)

Determination of Nitrogen Oxides Emissions from Stationary Sources
(Instrumental Analyzer Procedure)

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Emission Rate Calculation Using Oxygen-Based EPA Method 19

EPA Method 19 contains calculations (Equation 19-1) for determining mass emission rates using measured concentrations, heat input and either a published fuel factor or fuel factors calculated from an ultimate analysis. Equation 19-1 is an oxygen-based fuel factor calculation using dry basis pollutant and oxygen concentration measurements. Calculations are as follows:

$$E = C_d \times F_d \times 20.9 / (20.9 - \%O_2) \quad \text{Method 19, Equation 19-1}$$

Where,

E = emission rate in pounds per million Btu (lb/MMBtu)

C_d = dry concentration in pounds per dry standard cubic foot (lb/scf)

Conversions factors:

NO_x ppm x 1.194 x 10⁻⁷ = NO_x lb/scf

SO₂ ppm x 1.660 x 10⁻⁷ = SO₂ lb/scf

F_d = fuel factor in dry standard cubic feet per million Btu (dscf/MMBtu)

Method 19 published F_d factors for natural gas and oil are as follows:

Natural gas – 8710 dscf/MMBtu

Oil – 9190 dscf/MMBtu

Fuel factors may also be calculated from an ultimate analysis as follows:

$$F_d = \frac{K(K_{hd}\%H + K_c\%C + K_s\%S + K_n\%N - K_o\%O)}{GCV} \quad \text{Eq. 19-13}$$

K = 10⁶ Btu/MMBtu

K_{hd} = (3.64 scf/lb) / %

K_c = (1.53 scf/lb) / %

K_s = (0.57 scf/lb) / %

K_n = (0.14 scf/lb) / %

K_o = (0.46 scf/lb) / %

GCV = gross caloric value (Btu/lb)

EPA Method 10

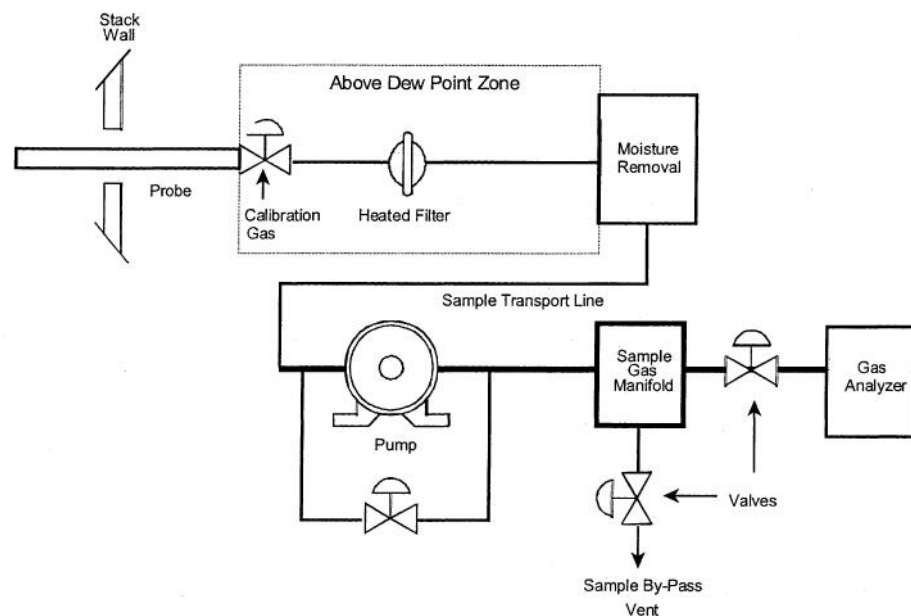
Determination of Carbon Monoxide Emissions from Stationary Sources (Instrumental Analyzer Procedure)

Page 1 / 3

SUMMARY

Effluent gas is continuously conveyed to an analyzer for measuring the concentration of CO. Alternatively, sample gas may be collected in a Tedlar bag followed by analysis with a calibrated analyzer.

SAMPLING TRAIN



Components:

- Glass or stainless steel probe of sufficient length to traverse required sample points.
- An in-stack or out-of-stack filter made of material which is non-reactive to the sample gas. The filter is not required where no significant particulate matter is present.
- Heated Sample line (250°F) made of Teflon or other material that does not absorb or alter the sample gas.
- Condenser or dryer to remove moisture from the sample gas if measuring on a dry basis.
- Leak-free pump constructed of non-reactive material to pull sample through the system at a sufficient rate to minimize the response time.
- Manifold constructed of non-reactive material to allow the introduction of calibration gases either directly to the analyzer or into the measurement system at the probe and to direct a portion of the sample to the analyzer while diverting the rest of the sample to a by-pass discharge vent.
- An analyzer capable of meeting all performance requirements that continuously measures CO.
- Computer based data acquisition system for recording measurements.

Revised: 08/2/2018

EPA Method 10

Determination of Carbon Monoxide Emissions from Stationary Sources (Instrumental Analyzer Procedure)

Page 2 / 3

SAMPLING PROCEDURES

- Assemble the sampling system and conduct a leak check.
- Confirm that all calibration gas certifications are complete and not expired.
- Conduct an analyzer calibration error test.
- Conduct an initial system bias check and response time test.
- Perform a stratification test to determine the number of sample traverse points.
- Position the probe at the first sampling point and purge the system for at least two times the response time. Traverse all required points sampling for equal time at each.
- Conduct a post-run system bias and drift assessment check.

QUALITY ASSURANCE

Measurement System:

- Calibration error is verified to be within $\pm 2\%$ of the calibration span or ± 0.5 ppmv difference
- System bias is verified to be within $\pm 5\%$ of the calibration span or ± 0.5 ppmv difference
- Drift is verified to be within $\pm 3\%$ of the calibration span or ± 0.5 ppmv difference

CO Analyzer:

- Analyzer used for testing has undergone manufacturer interference checks
- Analyzer resolution is $< 2.0\%$ full-scale range

Calibration Gas:

- Calibration uncertainty of $\pm 2\%$ certified value
- Low-level gas $< 20\%$ of calibration span
- Mid-level gas 40-60% of calibration span
- High-level gas sets the calibration span with test measurements 20-100% of this value

Data:

- Data collection and calculations are conducted on a reviewed computer based system
- Data resolution $\pm 0.5\%$ full-scale range
- Data recording frequency of 1-minute average
- Minute averages \pm calibration span
- Run average \pm calibration span

Revised: 08/2/2018



EPA Method 10

Determination of Carbon Monoxide Emissions from Stationary Sources
(Instrumental Analyzer Procedure)

Page 3 / 3

CALCULATIONS

Analyzer Calibration Error:

$$ACE = \frac{C_{DIR} - C_V}{C} \times 100$$

ACE Analyzer calibration error, percent of calibration span

C_V Manufacturer certified concentration of a calibration gas (low, mid, high), ppmv

C_{DIR} Measured concentration of a calibration gas when introduced in direct calibration mode, ppmv

CS Calibration span, ppmv

System Bias:

$$SB = \frac{C_S - C_{DIR}}{C} \times 100$$

SB System bias, percent of calibration span

C_S Measured concentration of a calibration gas when introduced in system calibration mode, ppmv

CS Calibration span, ppmv

Drift Assessment:

$$D = SB_{final} - SB_i$$

D Drift assessment, percent of calibration span

SB_{final} Post-run system bias, percent of calibration span

SB_i Pre-run system bias, percent of calibration span

Effluent Gas Concentration:

$$C_{Gas} = (C_{Avg} - C_O) \times \frac{C_{MA}}{C_M - C_O}$$

C_{Gas} Average effluent gas concentration adjusted for bias, ppmv

C_{Avg} Average unadjusted gas concentration indicated by data recorder for the test run, ppmv

C_O Average of initial and final system bias responses from the low-level (or zero) calibration gas, ppmv

C_{MA} Actual concentration of the upscale calibration gas, ppmv

C_M Average of initial and final system bias responses for the upscale calibration gas, ppmv.

Revised: 08/2/2018



EPA Method 18

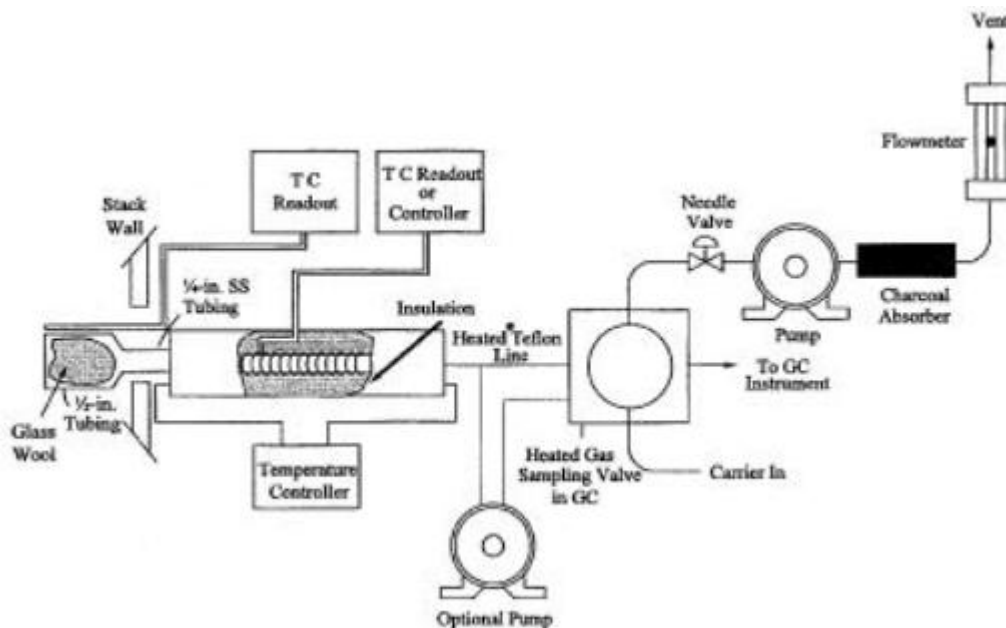
Gaseous Organic Compound Emissions by Gas Chromatography (Direct Interface Method)

Page 1 / 5

SUMMARY

Sample gas is continuously pumped through Teflon tubing to a gas chromatograph (GC) which analyzes a gas sample periodically for volatile organic compounds. A sampling train schematic is shown below and photographs are attached.

SAMPLING TRAIN



Sampling Components:

- ⌋ Glass or stainless steel probe of sufficient length to reach required sample points.
- ⌋ An in-stack or out-of-stack filter made of material which is non-reactive to the sample gas. The filter is not required where no significant particulate matter is present.
- ⌋ Sample line made of Teflon or other material that does not absorb or alter the sample gas. The sample line is heated to 110 °C.
- ⌋ Gas flow meter or critical orifice flow controller
- ⌋ Leak-free pump constructed of non-reactive material to pull sample through the system at a sufficient rate to minimize the response time.

Analytical Components

- ⌋ SRI Inc. Model 8610C gas chromatograph, laptop computer with Peaksimple software and USB cable
- ⌋ Restek MXT-1 60 meter steel capillary column (test protocol will specify other column type if required)
- ⌋ High purity hydrogen, nitrogen and air
- ⌋ CGA 350, 580 and 590 gas cylinder regulators with 1/8-inch tubing connectors
- ⌋ 1,000 cc gas syringe
- ⌋ Printer (optional as all chromatography files are saved)

Revised: 11/16/2018

EPA Method 18

Gaseous Organic Compound Emissions by Gas Chromatography (Direct Interface Method)

Page 2 / 5

SAMPLING PROCEDURES

-) Assemble the sampling system and conduct a vacuum leak check.
-) For critical orifice flow controllers, calibrate the sampling rate with a gas flow calibrator.
-) Position the probe at the first sampling point and purge the system for at least two times the response time.
-) Program GC software to inject samples at specified time intervals

ANALYTICAL PROCEDURES

-) Set up SRI Model 8610C chromatograph in accordance with manufacturer specifications.
-) Confirm that all calibration gas certifications are complete and not expired.
-) Conduct a 3-level calibration on the gas chromatograph for each target compound using commercially available gas standards. Each gas standard must be analyzed three times and the responses must be within 5% of the mean for each target compound.
-) Conduct a pre-test recovery study as per Section 8.4.1. Inject the mid-level calibration gas at the probe exit so that the gas passes through the entire sampling system (filter, heated line and pump). The measured concentration of at least one target compound must be within 10% of the certified value.
-) Insert probe to the center of stack or for large stacks to an insertion depth of at least 1 meter.
-) Program Peaksimple to automatically inject sample gas at specified intervals. Each run must include at least 5 sample analyses.
-) After completing sample analyses, re-analyze the mid-level calibration gas in triplicate. If the average value of each target compound is within 5% of the initial value, the initial calibration can be used to quantify the samples. If the post-test calibration varies by more than 5% of the initial calibration, then the 3-point calibration must be repeated and both pre and post-test calibrations must be used for sample quantification.

QUALITY ASSURANCE

Sampling System:

-) Sample flow rate should be $\pm 2\%$.
-) Leak rate should be 0.00 liters per minute at 5 inches Hg vacuum

Chromatography Analysis:

-) Standards, samples and spikes must be analyzed in triplicate and responses must be within 5% of the mean.
-) System spiked recovery as per Method 18, Section 8.4.1, must be within 10% of the analyzer response for at least one compound.

Calibration Gas:

-) Calibration uncertainty of 2% certified value
-) Gas used only prior to expiration date

Revised: 11/16/2018



EPA Method 18

Gaseous Organic Compound Emissions by Gas Chromatography
(Direct Interface Method)

Page 3 / 5

CALCULATIONS

Triplicate Injection:

$$\text{Dev} = \frac{(\text{RP}_{\text{avg}} - \text{RP})}{R} \times 100$$

RP Chromatograph response in area units

RP_{avg} Average response of three injections

Dev Deviation from the mean value

Drift Assessment:

$$D = \text{SB}_{\text{final}} - \text{SB}_i$$

D Drift assessment, percent of calibration span

SB_{final} Post-run system response for the mid-level gas

SB_i Pre-run system response for the mid-level gas

Spike Recovery Correction:

EPA Method 18 with the direct interface sampling option does not include a spike recovery correction. The calibration gas is injected as close as possible to the probe inlet and the response for at least one compound must be within $\pm 10\%$ of the certified value.

Detection Limit

Detection limit is determined by analyzing the low standard seven times and applying a standard statistical analysis. An example of the detection limit determination is shown below.

Standard Conc (ppm)	Response (ppm) ¹							Average	Standard Deviation	MDL (ppm) ²
	1	2	3	4	5	6	7			
1.00	1.181	1.129	1.166	1.171	1.183	1.185	1.182	1.1710	0.020	0.062

1. The low standard is analyzed 7 consecutive times.

2. MDL (ppm) = STDEV x 3.143

STDEV = standard deviation of the response for 7 injections of the low standard

3.143 = Student T-value for n-1 degrees of freedom at a 99% confidence

Revised: 11/16/2018



EPA Method 18

Gaseous Organic Compound Emissions by Gas Chromatography (Direct Interface Method)

Page 4 / 5

CALCULATIONS (CONTINUED)

Mass Emission Rate

Pollutant mass emission rate in pounds per hour (lb/hour) is calculated from the measured concentration and exhaust gas flow rate as follows:

$$ER = \text{ppmw} \times \text{molecular weight} \times \text{scfm} \times 15.58 \times 10^{-8}$$

ER = emission rate (lb/hour)

ppmw = parts per million by volume – wet basis

scfm = standard cubic feet per minute (wet)

Mass Basis Destruction Efficiency

Mass basis destruction efficiency is calculated with measured pollutant flow rates at the control device inlet and outlet using the following calculation:

$$\text{Destruction Efficiency (\%)} = (ER_{\text{in}} - ER_{\text{out}}) / ER_{\text{in}} \times 100$$

ER_{in} = control device inlet pollutant flow rate (lb/hour)

ER_{out} = control device outlet pollutant flow rate (lb/hour)

EPA Method 18

Gaseous Organic Compound Emissions by Gas Chromatography
(Direct Interface Method)

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COMPONENT IMAGES

SRI, Inc. Model 8610C Gas Chromatograph:



Revised: 11/16/2018

EPA Method 25a

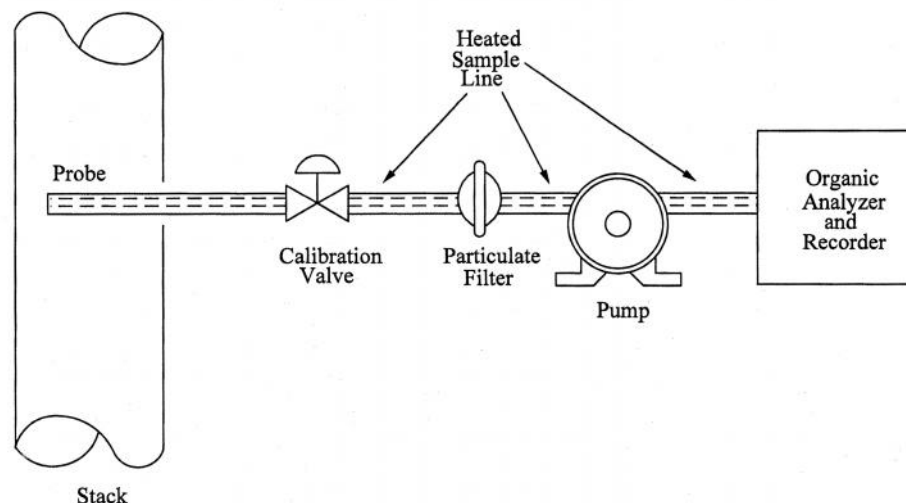
Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer

Page 1 / 3

SUMMARY

A gas sample is extracted from the source through a heated sample line and glass fiber filter to a flame ionization analyzer.

SAMPLING TRAIN



Components:

- Stainless steel probe heated to 220 °F.
- A glass fiber in-stack filter or a glass fiber out-of-stack filter heated to 220 °F. The filter is not required where no significant particulate matter is present.
- Teflon or stainless steel sample line heated to 220 °F.
- Leak-free pump constructed of non-reactive material to pull sample through the system at a sufficient rate to minimize the response time.
- Manifold constructed of non-reactive material to allow the introduction of calibration gases into the measurement system at the probe.
- Flame ionization analyzer capable of meeting all performance requirements.
- Computer based data acquisition system for recording measurements.

Revised: 08/2/2018

EPA Method 25a

Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer

Page 2 / 3

SAMPLING PROCEDURES

- Assemble the sampling system and conduct a leak check.
- Confirm that all calibration gas certifications are complete and not expired.
- Conduct an analyzer calibration error test sending gas through the entire measurement system.
- Conduct a response time test.
- Position the probe so that sample is collected from the centrally located 10% area of the stack.
- Begin sampling after 2 times the sampling response time has passed.
- Conduct a post-run drift assessment check.

QUALITY ASSURANCE

Measurement System:

- Calibration error is verified to be within $\pm 5\%$ of the calibration gas value
- Drift is verified to be within $\pm 3\%$ of the span value

Analyzer:

- Analyzer used for testing has undergone manufacturer interference checks
- Analyzer resolution is $< 2.0\%$ full-scale range

Calibration and Support Gas:

- Calibration uncertainty of 2% certified value
- High purity air zero gas < 0.1 ppmv organic material
- Low-level calibration gas 25-35% of the applicable span value
- Mid-level gas 45-55% of the applicable span value
- High-level gas 80-90% of the applicable span value
- Fuel consisting of 100% H_2

Data:

- Data collection and calculations are conducted on a reviewed computer based system
- Data resolution 0.5% full-scale range
- Data recording frequency of 1-minute average
- Minute averages calibration span
- Run average calibration span

Revised: 08/2/2018



EPA Method 25a

Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer

Page 3 / 3

CALCULATIONS

Analyzer Calibration Error:

$$ACE = \frac{C_S - C_V}{C_V} \times 100$$

ACE Analyzer calibration error, percent of calibration gas value

C_S Measured concentration of a calibration gas through the sampling system, ppmv

C_V Manufacturer certified concentration of a calibration gas (low, mid, high), ppmv

Drift Assessment:

$$D = \frac{C_S - C_i}{C} \times 100$$

D Drift assessment, percent of span

C_S Measured concentration of a calibration gas through the sampling system, ppmv

C_i Initial analyzer response, ppmv

C Calibration span, ppmv

EPA Method 202

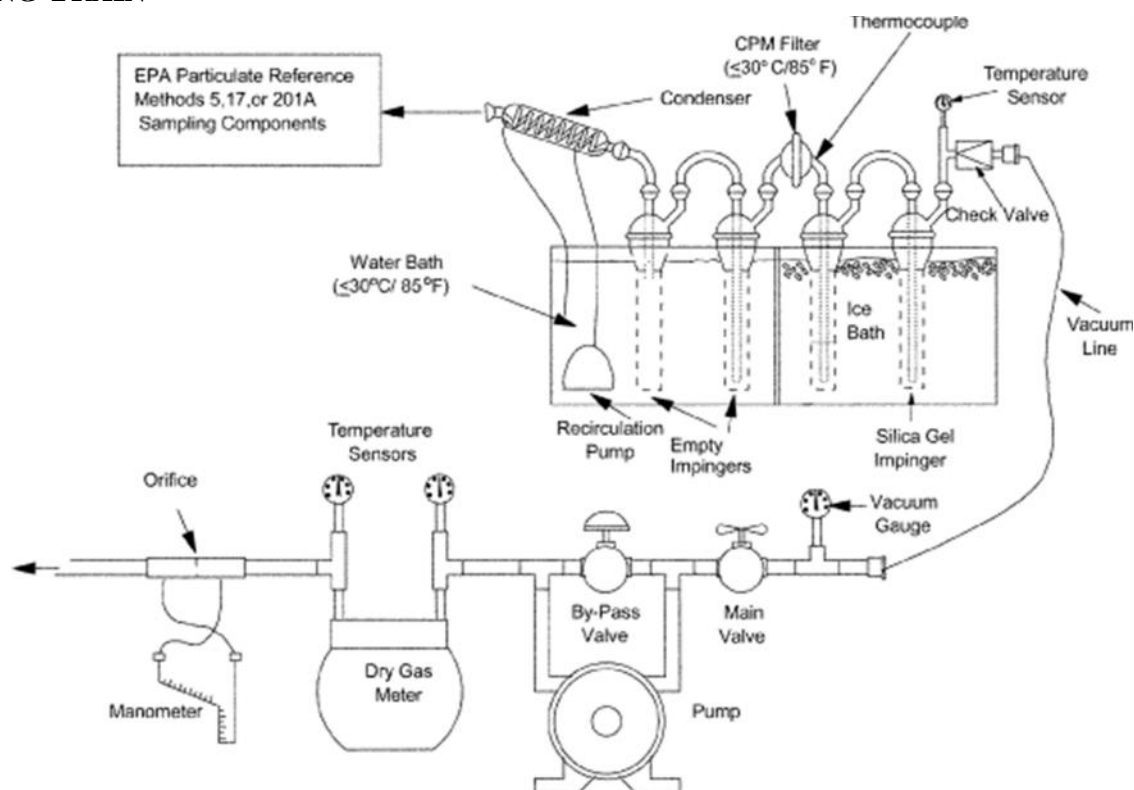
Method for Determining Condensable Particulate Emissions from Stationary Sources.

Page 1 / 5

SUMMARY

Particulate matter (PM) is withdrawn isokinetically from the source in accordance with EPA Methods 5, 17 or 201A. The Method 5, 17 and 201A front half sampling train components remove filterable particulate matter before the sample gas is drawn through the Method 202 components to collect condensable particulate matter (CPM). The Method 202 sampling train components begin with a glass coil condenser, followed by two dry impingers, and a Teflon filter. Condensate collected in the dry impingers and on the Teflon filter is recovered. The condensate and filter are extracted and organic and aqueous fractions are dessicated and weighed to determine the mass of total CPM.

SAMPLING TRAIN



Components:

- 1. Glass spiral condenser
 - 2. 2 impingers connected in series (≤ 85 °F)
 - 1. dropout impinger, empty
 - 2. modified Greenburg-Smith impinger, empty
 - 1. Glass or stainless steel filter holder and Teflon filter with thermocouple (65 °F and 85 °F)
 - 2. 2 impingers connect in series placed in an ice bath (impinger exit 68 °F)
 - 1. Modified Greenburg-Smith, 100 ml H₂O
 - 2. Modified Greenburg-Smith, indicating silica gel
 - Umbilical with leak-free vacuum line
 - Vacuum gauge, leak-free pump, temperature sensors and a calibrated dry gas meter
 - Dual inclined manometer or equivalent for measuring velocity head and orifice values

Revised: 06/4/2020

EPA Method 202

Method for Determining Condensable Particulate Emissions from Stationary Sources.

Page 2 / 5

SAMPLING PROCEDURES

-) Select sampling site and minimum number of sampling points according to EPA Method 1. Refer to Method 4, 17 or 201A for sampling specifications
-) Assemble the Method 202 sampling train components as shown above, weigh the impingers, place water around the first two impingers, activate the condenser recirculation pump, and place crushed ice around the third and fourth impingers.
-) Conduct a leak check from the tip of the nozzle at a vacuum equal to or greater than the highest anticipated during testing. Ensure that the leak rate is 0.020 cfm before starting a test run.
-) Place the probe at the first sampling point.
-) Begin sampling at the isokinetic rate in accordance with EPA Methods 5, 17 or 201A.
-) Traverse the stack using the predetermined sampling points.
-) Conduct a post-test leak check at a vacuum higher than the highest vacuum observed during sampling.

RECOVERY PROCEDURES

-) Weigh the impingers to determine moisture gain.
-) Conduct a pressurized purge of the CPM train by transferring water collected in the condenser and dropout impinger into the backup impinger. If the tip of the backup impinger does not extend below the water level, add a measured amount of degassed, deionized ultra-filtered water. Purge at a minimum of 14 liters per minute using filtered ultra-high purity nitrogen.
-) Container 1 (Aqueous liquid impinger contents) – Quantitatively transfer liquid from the dropout and the impinger prior to the CPM filter into a clean sample bottle (glass or plastic). Rinse the probe extension, condenser, each impinger and the connecting glassware, and the front half of the CPM filter twice with water. Recover the rinse water and add it to the same sample bottle. Mark the liquid level on the bottle.
-) Container 2 (Organic rinses) – Rinse the probe extension, condenser, each impinger and the connecting glassware, and the front half of the CPM filter twice with acetone. Then repeat the entire rinse procedure with two rinses of hexane, and save the hexane rinses in the same container as the acetone rinse. Mark the liquid level on the bottle.
-) Container 3 (CPM filter) – Place the filter in a labeled petri dish.
-) Acetone Field Reagent Blank – Take 200 ml of acetone directly from the wash bottle and place it in a clean, leak-proof container. Mark the liquid level on the bottle.
-) Water Field Reagent Blank – Take 200 ml of water directly from the wash bottle and place it in a clean, leak-proof container. Mark the liquid level on the bottle.
-) Hexane Field Reagent Blank – Take 200 ml of water directly from the wash bottle and place it in a clean, leak-proof container. Mark the liquid level on the bottle.
-) Field Train Recover Blank – After the first or second run, add 100 ml of water to the first impinger, purge and recover the assembled train as above. This blank weight will be subtracted from the field sample weights (max of 2.0 mg).

Revised: 06/4/2020



EPA Method 202

Method for Determining Condensable Particulate Emissions from Stationary Sources.

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ANALYTICAL PROCEDURES

-) Container 3 – Conduct triplicate extractions of the inorganic fraction of the CPM filter using deionized, ultra-filtered water and combine with container 1. Conduct triplicate extractions of the organic fraction of the CPM filter using hexane and combine with container 2.
-) Container 1 – Use hexane to extract the organic fraction and add it to container 2. Transfer the remaining aqueous fraction to a tarred beaker, evaporate to dryness, desiccate for 24 hours, and weigh to a constant weight to the nearest 0.1 mg.
-) Container 2 – Transfer the organic fraction to a tarred beaker, evaporate to dryness, desiccate for 24 hours, and weigh to a constant weight to the nearest 0.1 mg.
-) Acetone Field Reagent Blank - Transfer 150 ml of the acetone to a tarred beaker, evaporate to dryness at room temperature and pressure in a laboratory hood, desiccate for 24 hours, and weigh to a constant weight to the nearest 0.1 mg.
-) Water Field Reagent Blank - Transfer 150 ml of the water to a tarred beaker, evaporate to dryness, desiccate for 24 hours, and weigh to a constant weight to the nearest 0.1 mg.
-) Hexane Field Reagent Blank - Transfer 150 ml of the hexane to a tarred beaker, evaporate to dryness at room temperature and pressure in a laboratory hood, desiccate for 24 hours, and weigh to a constant weight to the nearest 0.1 mg.
-) Field Train Recover Blank – Analyze following the same procedures as above.

QUALITY ASSURANCE

Equipment

-) Pitot tubes, thermocouples, nozzles, and dry gas meters are calibrated annually.
-) All glassware is cleaned and baked (6 hours at 300 °C) prior to field use.
-) Probe, filter, and impinger exit temperatures are carefully monitored during testing to ensure the values are maintained within the appropriate range.
-) The entire sampling train is leak checked post run from the tip of the nozzle at a vacuum equal to or greater than the maximum value reached during the test run.
-) Sampling rate is verified to be within 10% isokinetic variation (90%-110%).
-) The dry gas meter calibration factor is verified after field use to be within 5% of the annual value.

Samples

-) New containers are used to collect samples.
-) Each sample container is clearly labeled.
-) A chain of custody is generated for all samples.
-) Samples are transported upright in protective packaging.

Data

-) Field data are recorded on prepared forms.
-) Only reviewed spreadsheets are used to conduct data reduction calculations.
-) All data and deliverables undergo peer review with a signoff form.

Revised: 06/4/2020



EPA Method 202

Method for Determining Condensable Particulate Emissions from Stationary Sources.

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CALCULATIONS

Dry Gas Volume:

$$V_{m(s)} = V_m Y \frac{T_s \left(P_{bar} + \frac{\Delta}{13.6} \right)}{T_m P_s}$$

- $V_{m(std)}$ Volume of gas sample measured by the dry gas meter, corrected to standard conditions, dscf
 V_m Volume of gas sample as measured by dry gas meter, dcf
 Y Dry gas meter calibration factor
 T_{std} Standard absolute temperature, 528 °R
 P_{bar} Barometric pressure at the sampling site, inHg
 H Average pressure differential across the orifice meter, inH₂O
 T_m Absolute average DGM temperature, °R
 P_{std} Standard absolute pressure, 29.92 inHg

Volume of Water Vapor Condensed:

$$V_{w(s)} = K_2 V_{lc}$$

- $V_{w(std)}$ Volume of water vapor in the gas sample, corrected to standard conditions, scf
 K_2 0.04706 ft/ml for English units
 V_{lc} Total volume of liquid collected in impingers and silica gel

Moisture Content:

$$B_w = \frac{V_{w(s)}}{V_{m(s)} + V_{w(s)}}$$

- B_{ws} Water vapor in the gas stream, proportion by volume
 $V_{w(std)}$ Volume of water vapor in the gas sample, corrected to standard conditions, scf

Condensable Particulate Matter (CPM) Concentration:

$$C_{cr} = \frac{m_{cl}}{V_{m(s)}}$$

- C_{cpm} Concentration of condensable particulate matter in stack gas, dry basis, corrected to standard conditions, mg/dscf
 M_{cpm} Total amount of condensable particulate matter collected, mg

Revised: 06/4/2020



EPA Method 202

Method for Determining Condensable Particulate Emissions from
Stationary Sources.

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CALCULATIONS (CONTINUED)

Isokinetic Variation:

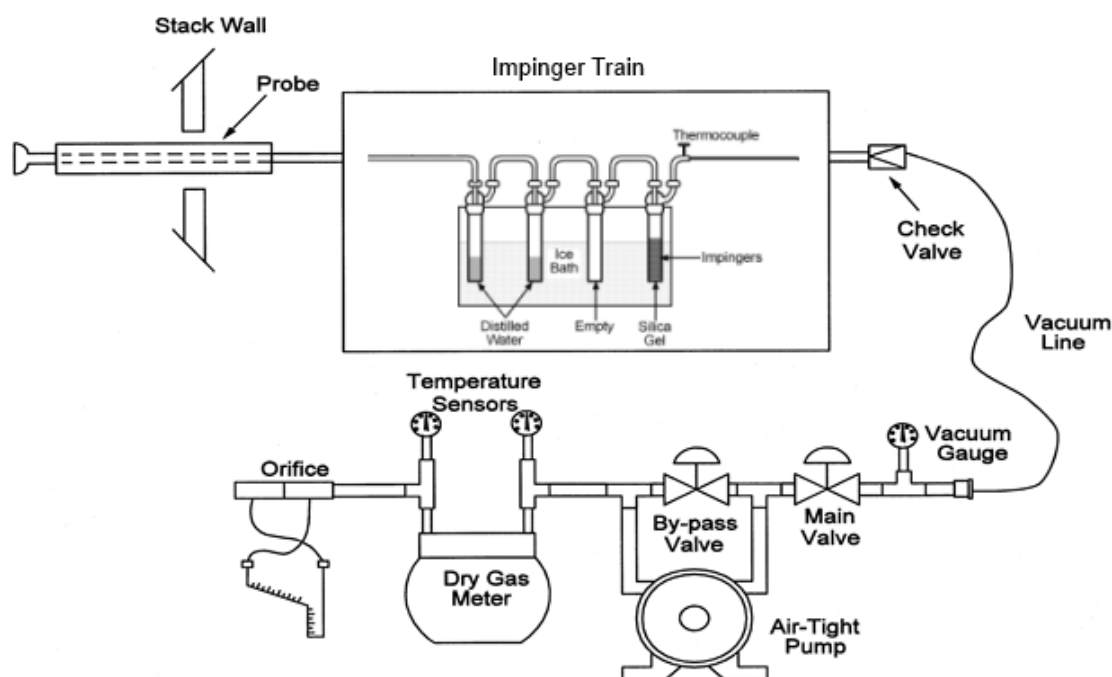
$$I = \frac{100T_s \left[K_4 V_{li} + \frac{(V_m Y)}{T_m} \left(P_{\text{bar}} + \frac{\Delta H}{13.6} \right) \right]}{60 \theta v_s P_s A_n}$$

T_s	Absolute average stack gas temperature, °R
K_4	0.002669 ((inHg)(ft))/((ml)(°R)) for English units
V_{li}	Total volume of liquid collected in impingers & silica gel, ml
	Total sampling time, min
V_s	Stack gas velocity, ft/sec
P_s	Absolute stack gas pressure, inHg
A_n	Cross-sectional area of nozzle, ft ²

SUMMARY

This procedure describes a modified version of EPA Method 323 for sampling and analysis of formaldehyde emissions in the exhaust of natural gas-fired stationary combustion sources. The modifications provide for dramatically lower detection limits required for testing low emitting sources. An emission sample from the combustion exhaust is drawn through an impinger train containing chilled reagent water to absorb formaldehyde. The formaldehyde concentration in the impinger is determined using the modified pararosaniline method. Formaldehyde in the sample reacts with acidic pararosaniline and sodium sulfite, forming a purple chromophore. The intensity of the purple color, measured spectrophotometrically, provides an accurate and precise measure of the formaldehyde concentration in the sample.

SAMPLING TRAIN



Components:

- Glass or quartz lined probe sufficiently heated to prevent condensation.
- 4 impingers connected in series and placed in an ice bath (impinger exit < 68 °F)
 1. Modified Greenburg-Smith, ~100 ml water
 2. Greenburg-Smith, ~100 ml water
 3. Modified Greenburg-Smith, empty
 4. Modified Greenburg-Smith, indicating silica gel
- Umbilical with leak-free vacuum line
- Vacuum gauge, leak-free pump, temperature sensors and a calibrated dry gas meter
- Inclined manometer or equivalent for measuring orifice values

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SAMPLING PROCEDURES

- Weigh the impinger train.
- Conduct a leak check from the tip of the probe. Ensure leak rate is ≤ 0.020 cfm before starting a test run.
- Place the probe at the desired sampling point and record the initial dry gas meter reading.
- Begin sampling at a rate of approximately 0.75 cubic feet per minute. Collect sample data every 10 minutes including delta H, impinger outlet temperature, and dry gas meter inlet and outlet temperature.
- At the end of the sampling period, close the coarse adjust valve and record the final dry gas meter reading.
- Conduct a post-test leak check from the tip of the probe at a vacuum higher than observed during sampling.

RECOVERY PROCEDURES

- Weigh the impinger train and calculate the moisture content.
- Container 1 – Transfer the impinger contents to a 500 ml wide-mouth polyethylene bottle. Rinse the probe, first three impingers, and connecting glassware and collect in the same container as the impinger contents. Tighten the lid, mark the fluid level, and label the contents.
- Container 2 – Blank – Transfer reagent water into a 500 ml wide-mouth polyethylene bottle equivalent in quantity to the total collected for the sample. Tighten the lid, mark the fluid level, and label the contents.
- Samples should be stored on ice and analyzed within 14-days of collection.

ANALYTICAL PROCEDURES

- Analyze samples following the modified pararosaniline method described in section 11 of EPA Method 316.

QUALITY ASSURANCE

Equipment:

- Dry gas meters are calibrated annually and after each field program.
- All glassware is cleaned prior to field use.
- Impinger exit temperature is monitored during testing to verify compliance with method specification.
- A leak checked is conducted post run at a vacuum equal to or greater than the maximum value reached during the test run.
- The dry gas meter calibration factor is verified after field use to be within 5% of the annual value.

Samples:

- New containers are used to collect samples.
- Each sample container is clearly labeled.
- A chain of custody is generated for all samples.
- Samples are transported upright in protective packaging on ice.

Data:

- Field data are recorded on prepared forms.
- Only reviewed spreadsheets are used to conduct data reduction calculations.
- All data and deliverables undergo peer review.

CALCULATIONS

Dry Gas Volume:

$$V_{m(std)} = V_m Y \frac{T_{std} \left(P_{bar} + \frac{\Delta H}{13.6} \right)}{T_m P_{std}}$$

$V_{m(std)}$	Volume of gas sample measured by the dry gas meter, corrected to standard conditions, dscf
V_m	Volume of gas sample as measured by dry gas meter, dcf
Y	Dry gas meter calibration factor
T_{std}	Standard absolute temperature, 528 °R
P_{bar}	Barometric pressure at the sampling site, inHg
ΔH	Average pressure differential across the orifice meter, inH ₂ O
T_m	Absolute average DGM temperature, °R
P_{std}	Standard absolute pressure, 29.92 inHg

Volume of Water Vapor Condensed:

$$V_{w(std)} = K_2 V_{lc}$$

$V_{w(std)}$	Volume of water vapor in the gas sample, corrected to standard conditions, scf
K_2	0.04706 ft/ml for English units
V_{lc}	Total volume of liquid collected in impingers and silica gel

Moisture Content:

$$B_{ws} = \frac{V_{w(std)}}{V_{m(std)} + V_{w(std)}}$$

B_{ws}	Water vapor in the gas stream, proportion by volume
$V_{w(std)}$	Volume of water vapor in the gas sample, corrected to standard conditions, scf

Formaldehyde Concentration:

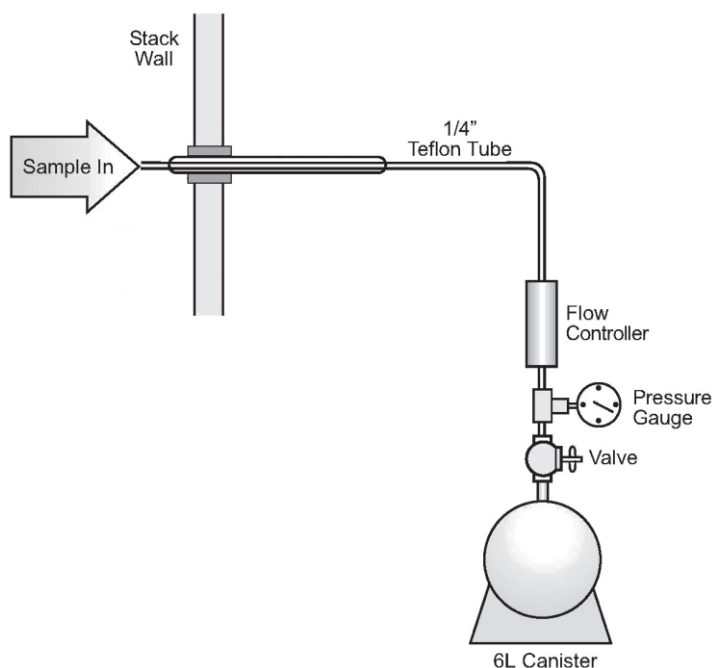
$$C_{s\ CH_2O} = \frac{24.05\ N}{28.3168\ V_{mstd}\ MW}$$

N	Formaldehyde concentration, µg
MW	Molecular weight of formaldehyde, 30.031 g/mol

SUMMARY

Gas is collected using an evacuated stainless-steel sample canister and analyzed by gas chromatography mass spectrometry (GC/MS) for volatile organic compounds.

SAMPLING TRAIN



Components:

- Sample line of Teflon tubing with ¼ inch outside diameter.
- Flow controller designed to sample at a constant rate throughout the sampling period.
- Pressure gauge.
- Valve
- Stainless steel 6-liter sample canister

SAMPLING PROCEDURES

- Assemble the sampling system as described above.
- Open valve to begin sampling.
- Record sampling data including time and pressure readings on a prepared form.
- Close valve to end sampling.
- Disconnect canister, cap, and label.

QUALITY ASSURANCE

- Sample line kept as short as feasible.
- Canisters are cleaned and leak checked in the lab prior to sampling.

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